Sheet (2)

Basic Properties of Fluids

1- A certain gasoline weighs 46.5 lb/ft^3. What are its mass density, specific volume, and specific gravity?

2- If an object has a mass of 2.0 slugs at sea level, what would its mass be at a location where the acceleration due to gravity is 30.00 ft/s^2?

3- The weight of a body is 100 lb. Determine

a) Its weight in newtons,

b) Its mass in kilograms, and

c) The rate of acceleration [in both feet per second per second (ft/s^2) and meters per second per second (m/s^2)] if a net force of 50 lb is applied to the body.

4- Verify the dimensions, in both the FLT system and the MLT system, of the following quantities:

a) The product of force times volume.

b) The product of pressure times mass divided by area.

c) Moment of force divided by velocity.

d) The product of volume times mass divded by velocity.

5- According to information found in an old hydraulics book, the energy loss per unit weight of fluid flowing through a nozzle connected to a hose can be estimated by the formula

$$h = (0.04 \text{ to } 0.09)(D/d)^4 V^2/2g$$

Where, h is the energy loss per unit weight, D is the hose diameter , d is the nozzle tip diameter, V is the

fluid velocity in the hose , and g the acceleration of gravity. Do you think this equation is dimensionally homogenous or not?

Do you think this equation is valid in any system of units? Explain.

6- A formula for estimating the volume rate of flow,Q, over the spillway of a dam is

$$Q = C\sqrt{2g}\,B(H + V^2/2g)^{3/2}$$

Where, C is a constant, g the acceleration of gravity, B the spillway width, H the depth of water passing over the spillway, and V the velocity of water just upstream of the dam.Would this equation be valid in any system of units? Explain.

7- Express the following quantitites in SI units:

a) 4.81 *slugs.*

b) 3.02 *lb*

c) 73.1 ft/s^2

d) 0.0234 $lb.s/ft^2$

e) 10.2 *in/min*

f) 79.1 *hp*

g) 15 *gallons(U.S.)*

8- Verify the conversion relationships for:

a) Acceleration

b) Density

c) Pressure

d) Volume flow rate

e) Specific weight

Use the basic conversion relationships: 1m=3.2808 ft; 1N=0.22481 lb;and 1 kg=0.068521 slug.

density and specific weight? Express your answer in SI units.

14- If 200 ft^3 of oil weighs 10 520 lb, calculate its specific weight, and density.

15- A vertical, cylinderical tank with a diameter of 12 m and a depth of 4 m is filled to the top with water at 20°C. If the water is heated to 50°C, how much water will spill over?

16- A vertical glass cylinder contains 900.00 mL of water at 10 °C; the height of the water column is 90.00 cm. The water and its container are heated to 80 °C. Assuming no evaporation, what will be the height of the water if the coefficient of thermal expansion (α) for the glass is 3.6 x 10^{-6} $°C^{-1}$?

Given: The water density at 10 °C = 1000 kg/m^3, and the water density at 80 °C = 971 kg/m^3

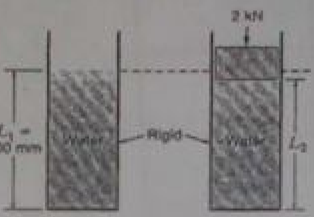
17- If the specific volume of a gas is 0.7 m^3/kg, what is its specific weight in N/m^3?

18- A certain as weighs 16 N/m^3 at a certain temperature and pressure. What are the values of its density, specific voulme, and spcific gravity relative to air weighing 12 N/m^3?

19- At normal atmospheric conditions, approximately what pressure in *psi* must be applied to water to reduce its volume by 2%? Given $E_v \approx 320{,}000$ *psi.*

Resolve the problem but decrease the volume by 3% and find the pressure in *MPa*.

20- **A rigid cylinder (Figure 1), inside diameter 15 mm, contains a column of water 500 mm long. What will the column length be if a force of 2 KN is applied to its end by a frictionless plunger? Assume no leakage. Given** $E_v \approx$ *320,000 psi.*



(Figure 1)

21- **At a depth of 4 miles in the ocean the pressure is 9520 psi . Assume specific weight at the surface is 64.00 lb/ft^3 and the average volume modulus is 320.000 psi for that pressure range.(Figure 2)**

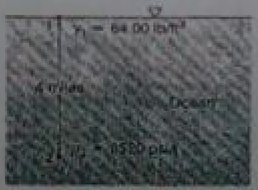
a) What will be the change in specific volume between that at surface and at that depth?

b) What will be the specific volume at that depth?

c) What will be the specific weight at that depth?

d) What is the percentage change in the specific volume?

e) What is the percentage change in the specific weight?



(Figure 2)

22- The temperature dependence of liquid viscosity is the phenomenon by which liquid viscosity tends to decrease as its temperature increases. Viscosity of water can be predicted with accuracy to within 2.5% from 0 °C to 370 °C by the following expression:

$$\mu(kg/ms) = 2.414 \times 10^{-5} \times 10^{(247.8K/(Temp-140K))}$$

Calculate the dynamic viscosity and kinematic viscosity of water at 20 °C respectively. You may assume that water is incompressible, and its density is 1000 kg/m^3.

23- A shaft 100 mm diameter (D) runs in a bearing 200 mm long (L). The two surfaces are separated by an oil film 2.5 mm thick (h). Take the oil viscosity (μ) as 0.25 kg/ms. if the shaft rotates at a speed of (N) revolutions per minute.

a) Show that the torque exerted on the bearing is given as:

$$Torque = \frac{\mu \times \pi^2 \times N \times L}{120 \times h} \times D^3$$

b) Calculate the torque necessary to rotate the shaft at 600 rpm.

24- A blimp is approximated by a prolate spheroid 90 m long and 30 m in diameter. Estimate the weight of 20°C gas within the blimp for

a) Helium at 1.1 atm

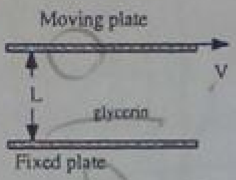
b) Air at 1.0 atm. What might the difference between these two values represent?

<u>Given</u> The volume of a prolate spheroid is

$$\forall = \frac{2}{3} \pi L R^2$$

25- In the shown (Figure 3), if the fluid is glycerin at 20°C and the width between plates is 6 mm, what shear stress (in Pa) is required to move the upper plate at V = 5.5 m/s? What is the flow Reynolds number if "L" is taken to be the distance between plates?

Given: Reynolds number ($Re = \frac{\rho V L}{\mu}$),for glycerin at 20°C, $\mu \approx 1.5\ N \cdot s/m^2$ .The density of glycerin at 20°C is 1264 kg/m^3



(Figure 3)

26- A flat plate 200 mm x 750 mm slides on oil (μ = 0.85 $N.s/m^2$) over a large plane surface (Figure 4). What force F is required to drag the plate at a velocity *v* of 1.2 m/s, if the thickness *t* of the separation oil film is 0.6 mm?



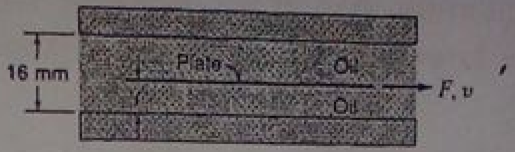
(Figure 4)

27- A space 16 mm wide between two large plane surfaces is filled with SAE 30 Western lubricating oil at 35 °C (Figure 5). What force F is required to drag a very thin plate of 0.4 m^2 area between the surfaces at a speed v= 0.25 m/s

a) If this plate is equally spaced between the two surfaces?

b) If t= 5 mm?

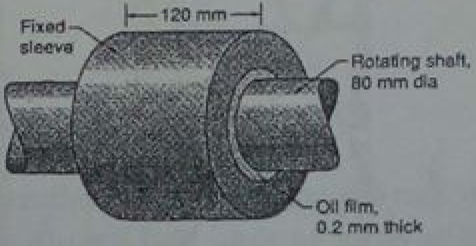
Given μ= 0.18 $N.s/m^2$



(Figure 5)

28- A journal bearing consists of an 80-mm shaft in an 80.4-mm sleeve 120 mm long, the clearance space (assumed to be uniform) being filled with SAE 30 Western lubricating oil at 40°C (Figure 6). Calculate the rate at which heat is generated at the bearing when the shaft turns at 150 rpm. Express the answer in *kN.m/s, J/s , Btu/hr , ft.lb/sec and hp.*

Given $\mu = 0.11$ N.s/m^2



(Figure 6)

29- A simple viscometer measures the time t for a solid sphere to fall a distance L through a test fluid of density ρ. The fluid viscosity μ is then given by

$$\mu \approx \frac{W_{net}\, t}{3\pi DL} \qquad if \quad t \geq \frac{2\rho DL}{\mu}$$

Where D is the sphere diameter and Wnet is the sphere net weight in the fluid.

Show that both of these formulas are dimensionally homogeneous.

Suppose that a 2.5 mm diameter aluminum sphere (density 2700 kg/m^3) falls in an oil of density 875

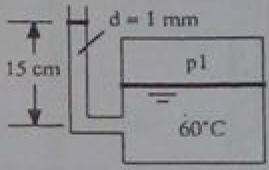
kg/m^3.If the time to fall 50 cm is 32 s, estimate the oil viscosity and verify that the inequality is valid.

30- The system in (Figure7) is used to estimate the pressure p_1 in the tank by measuring the 15-cm height of liquid in the 1-mm-diameter tube. The fluid is at 60° C. Calculate the true fluid height in the tube and the percent error due to capillarity if the fluid is:

a) Water; Water at 60°C: $\gamma \approx 9640$ N/m3, $\theta \approx 0°$ σ_{water} = 0.066

b) Mercury; Mercury at 60° C: $\gamma \approx 132200$ N/m3, $\theta \approx$ 130°

$\sigma_{mercury}$ = 0.47 N/M



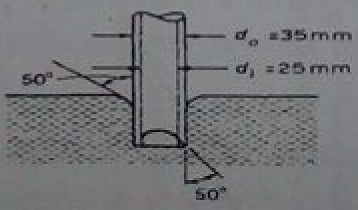
(Figure 7)

31- Two clean, parallel glass plates, separated by a distance d = 1.5 mm, are dipped in a bath of water. How far does the water rise due to capillary action, if σ = 0.0730 N/m?

γ = 9790 N/m3

32- A glass tube is inserted in mercury (Figure 8); the common temperature is 20 °C. What is the upward force on the glass as a result of surface effects?

σ = 0.514 N/M



(Figure 8)

33- Derive an expression for capillary rise (or depression) between two vertical parallel plates. How would you expect 10°C water to rise (in mm) if the clean glass plates are separated by 1.2 mm)?

Given: for water $\theta=0°$, water at 10°C $\gamma = 9804\ N/m^3$, $\sigma=$ 0.0742 N/m

34- By how much does the pressure inside a 2-mm diameter air bubble in 15°C water exceed the pressure in the surrounding water?

Given: for water at 15°C $\sigma= 0.0735$ N/m

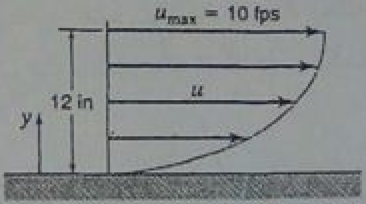
35- A 10.000-in-diameter plunger slides in a 10.006-in-diameter cylinder, the annular space being filled with oil having a kinematic viscosity of 0.004 ft^2/s and specific gravity of 0.85. If the plunger moves at 0.6 ft/s, find the frictional resistance when 9 ft is engaged in the cylinder.

36- A cylinder of 0.122-m radius rotates concentrically inside a fixed cylinder of 0.128-m radius. Both cylinders are 0.305 m long. Determine the viscosity of the liquid that fills the space between the cylinders if a torque of 0.881 N · m is required to maintain an angular velocity of 60 revolutions per minute.

37- In using a rotating cylinder viscometer, a bottom correction must be applies to account for the drag on the flat bottom of the inner cylinder. Calculate the theortical amount of this torque correction, neglecting the centrifugal effects, for a cylinder of a diameter d, rotated at a constant

angular velocity ω, in a liquid of absolute vicosity μ, with a clearnce Δh between the bottom of the inner cylinder and the floor of the outer one.

38- Assuming a velocity distribution as shown in (Figure 9) which is a parabola having its vertex 12 in from the boundary, calculate the velocity gradient for y= 0,3,6,9 and 12 in. Also calculate the shear stresses in Ib/ft^2 at these points if the fluid's absolute viscosity is 600 cP.



(Figure 9)

39- A hydraulic lift of the type commonly used for greasing automobiles consists of a 280 mm diameter ram which slides in a 280.18 mm diameter cylinder (similar to Figure 10), the annular space being filled with oil having a kinematic viscosity of 0.00042m2/s and specific gravity of 0.86. If the rate of travel of the ram is 0.22 m/s, find the frictional resistance when 2 m of the ram is engaged in the cylinder.



(Figure 10)

40- Contrary to what you might expect, a solid steel ball can float on water due to the surface tension effect. Determine the maximum diameter of a steel ball that would float on water at 20°C. What would your answer be for an aluminum ball?

Given: The densities of steel and aluminum balls to be 7800 kg/m^3 and 2700 kg/m^3, respectively.

The surface tension of water at 20°C is $\sigma_s = 0.073$ N/m. The contact angle is taken to be 0°.

41- Design an experiment to measure the viscosity of liquids using a vertical funnel with a cylindrical reservoir of height h and a narrow flow section of diameter D and length L. Making appropriate assumptions, obtain a relation for viscosity in terms of easily measurable quantities such as density and volume flow rate.